# Abrupt Climate Change

By Richard B. Alley

In the Hollywood disaster thriller *The Day after Tomorrow,* a climate catastrophe of ice age proportions catches the world unprepared. Millions of North Americans flee to sunny Mexico as wolves stalk the last few people huddled in freeze-dried New York City. Tornadoes ravage California. Giant hailstones pound Tokyo.

Are overwhelmingly abrupt climate changes likely to happen anytime soon, or did Fox Studios exaggerate wildly? The answer to both questions appears to be yes. Most climate experts agree that we need not fear a full-fledged ice age in the coming decades. But sudden, dramatic climate changes have struck many times in the past, and they could happen again. In fact, they are probably inevitable.

Inevitable, too, are the potential challenges to humanity. Unexpected warm spells may make certain regions more hospitable, but they could magnify sweltering conditions elsewhere. Cold snaps could make winters numbingly harsh and clog key navigation routes with ice. Severe droughts could render once fertile land agriculturally barren. These consequences would be particularly tough to bear because climate changes that occur suddenly often persist for centuries or even thousands of years. Indeed, the collapses of some ancient societies—once attributed to social, economic and political forces—are now being blamed largely on rapid shifts in climate.

The specter of abrupt climate change has attracted serious scientific investigation for more than a decade, but it has only recently captured the interest of

**Winter temperatures plummeting six degrees Celsius and sudden droughts scorching farmland around the globe are not just the stuff of scary movies. Such striking climate jumps have happened before—sometimes within a matter of years**

SLIM FILMS

SUDDEN FLIP-FLOPS are an unavoidable element of earthly climate.

filmmakers, economists and policymakers. Along with more attention comes increasing confusion about what triggers such change and what the outcomes will be. Casual observers might suppose that quick switches would dwarf any effects of human-induced global warming, which has been occurring gradually. But new evidence indicates that global warming should be more of a worry than ever: it could actually be pushing the earth's climate faster toward sudden shifts.

## Jumping Back and Forth

SCIENTISTS MIGHT NEVER have fully appreciated the climate's ability to lurch into a radically different state if not for ice cores extracted from Greenland's massive ice sheet in the early 1990s. These colossal rods of ice—some three kilometers long—entomb a remarkably clear set of climate records spanning the past 110,000 years. Investigators can distinguish annual layers in the ice cores and date them using a variety of methods; the composition of the ice itself reveals the temperature at which it formed.

Such work has revealed a long history of wild fluctuations in climate—long deep freezes alternating with brief warm spells. Central Greenland experienced cold snaps as extreme as six degrees Celsius in just a few years. On the other hand it achieved roughly half of the heating sustained since the peak of the last ice age—more than 10 degrees C—in a mere decade. That jump, which occurred about 11,500 years ago, is the equivalent of Minneapolis or Moscow acquiring the relatively sultry conditions of Atlanta or Madrid.

Not only did the ice cores reveal what happened in Greenland, but they also hinted at the situation in the rest of the world. Researchers had hypothesized that the 10-degree warming in the north was part of a warming episode across a broad swath of the Northern Hemisphere and that this episode enhanced precipitation in that region and far beyond. In Greenland itself, the thickness of the annual ice layers showed that, indeed, snowfall had doubled in a single year. Analyses of old air bubbles caught in the ice corroborated the prediction of increased wetness in other areas. In particular, measurements of methane in the bubbles indicated that this swamp gas was entering the atmosphere 50 percent faster during the intense warming than it had previously. The methane most likely entered the atmosphere as wetlands flooded in the tropics and thawed up north.

The cores also contained evidence that helped scientists fill in other details about the environment at various times. Ice layers that trapped dust from Asia indicated the source of prevailing winds, for instance. Investigators concluded that the winds must have been calmer during warm times because less wind-blown sea salt and ash from faraway volcanoes accumulated in the ice. And the list of clues goes on [see "Greenland Ice Cores: Frozen in Time," by Richard B. Alley and Michael L. Bender; SCIENTIFIC AMERICAN, February 1998].

Intense, abrupt warming episodes appeared more than 20 times in the Greenland ice records. Within several hundreds or thousands of years after the start of a typical warm period, the climate reverted to slow cooling followed by quick cooling over as short a time as a century. Then the pattern began again with another warming that might take only a few years. During the most extreme cold conditions, icebergs strayed as far south as the coast of Portugal. Lesser challenges probably drove the Vikings out of Greenland during the most recent cold snap, called the Little Ice Age, which started around A.D. 1400 and lasted 500 years.

Sharp warm-ups and cool-downs in the north unfolded differently elsewhere in the world, even though they may have shared a common cause. Cold, wet times in Greenland correlate with particularly cold, dry, windy conditions in Europe and North America; they also coincide with anomalously warm weather in the South Atlantic and Antarctica. Investigators pieced together these regional histories from additional clues they found in the ice of high mountain glaciers, the thickness of tree rings, and the types of pollen and shells preserved in ancient mud at the bottoms of lakes and oceans, among other sources.

The evidence also revealed that abrupt shifts in rainfall have offered up challenges rivaling those produced by tem-

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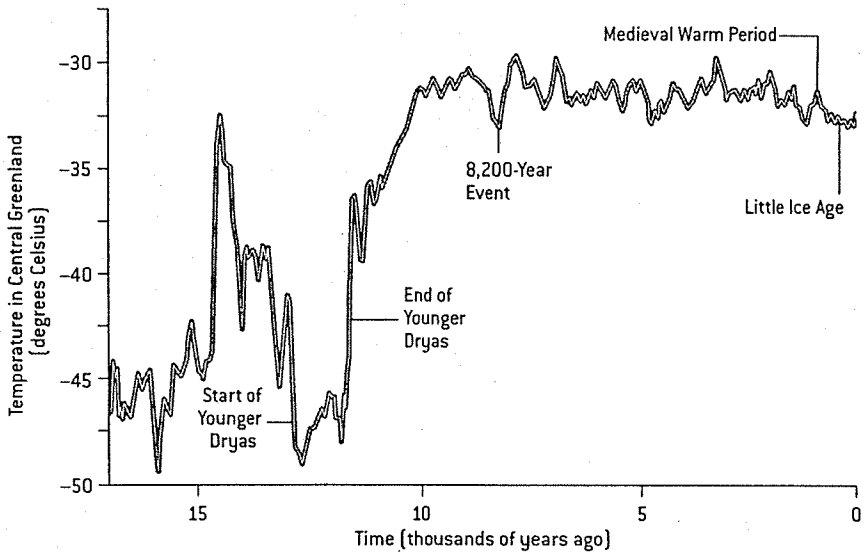
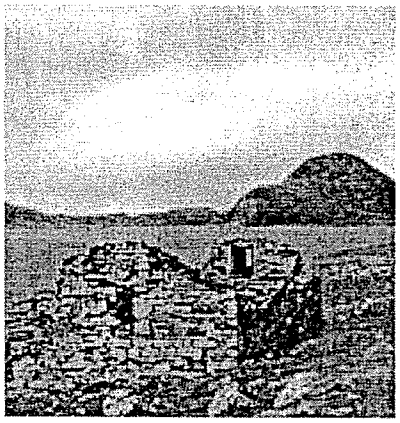
## Overview/*Inevitable Surprises*

- Most climate change policy discussions and research efforts center on global warming. But another problem looms as well: climate has suddenly flip-flopped in the past and will surely do so again.
- A regional drought could, for instance, arrive one summer and stay for decades, wiping out rich agricultural lands across Asia and North America; weather patterns in Europe could shift in a matter of years, making that area's climate more like Siberia's.
- Scientists cannot yet predict when such abrupt changes will occur, but most climate experts warn that global warming and human activities may be propelling the world faster toward sudden, long-lasting climate changes.

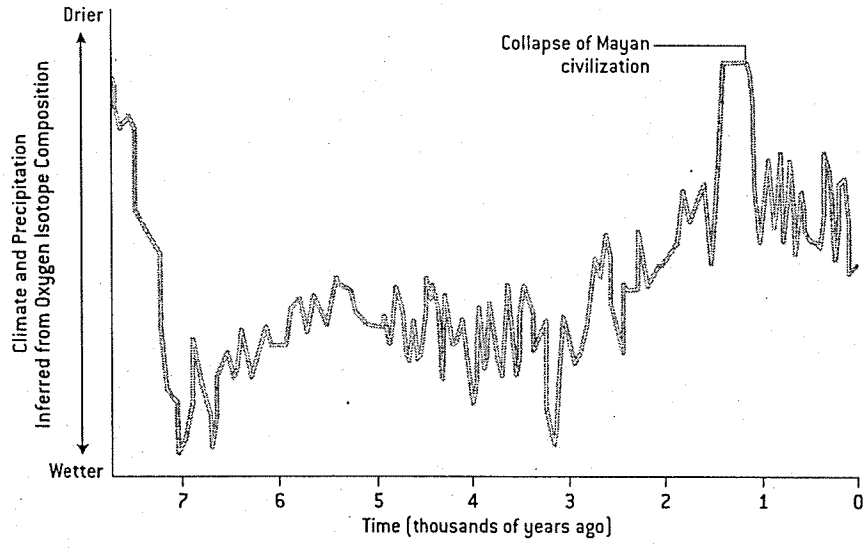
# PAST AS PROLOGUE?

Abrupt climate change has marked the earth's history for eons. Ice cores from Greenland, for instance, reveal that wild temperature swings (*top left*) punctuated the gradual warming that brought the planet out of the last ice age starting about 18,000 years ago. Fossil shells in lake sediments from Mexico's Yucatán Peninsula record sudden and severe droughts (*bottom left*) because a diagnostic ratio of oxygen isotopes in the shells shoots up when more water evaporates from the lake than falls as rain. Societies have often suffered as a result of these rapid shifts (*photographs*).



Viking settlement, now in ruins, was among those in Greenland abandoned during an abrupt cold spell called the Little Ice Age.




Mayan rain god (*statue in foreground*) was apparently no match for the drought now widely blamed for the collapse of Mayan civilization about 1,100 years ago.

perature swings. Cold times in the north typically brought drought to Saharan Africa and India. About 5,000 years ago a sudden drying converted the Sahara from a green landscape dotted with lakes to the scorching, sandy desert it is today. Two centuries of dryness about 1,100 years ago apparently contributed to the end of classic Mayan civilization in Mexico and elsewhere in Central America. In modern times, the El Niño phenomenon and other anomalies in the North Pacific occasionally have steered weather patterns far enough to trigger surprise droughts, such as the one responsible for the U.S. dust bowl of the 1930s.

## Point of No Return

BE THEY WARM SPELLS, cold snaps or prolonged droughts, the precipitous climate changes of the past all happened for essentially the same reason. In each case, a gradual change in temperature or other physical condition pushed a key driver of climate toward an invisible threshold. At the point that threshold was crossed, the climate driver—and thus the climate as well—flipped to a new and different state and usually stayed there for a long time [*see box on next page*].

Crossing a climate threshold is similar to flipping a canoe. If you are sitting in a canoe on a lake and you lean gradually to one side, the canoe tips, too. You are pushing the canoe toward a threshold—the position after which the boat

ELIZA JEWETT; SOURCES: M. STUIVER ET AL. AND K. CUFFEY ET AL. (*top graph*) AND D. HODELL ET AL. (*bottom graph*) *National Geophysical Data Center*; RUDY BRUEGGEMANN (*top photo*); FREELANCE CONSULTING SERVICES PTY LTD/CORBIS (*bottom photo*)